Androscoggin River Total Maximum Daily Load

Gulf Island Pond

Livermore Falls Impoundment

Final

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TMDL Summary – Submittal Template

Description of Waterbody, Pollutants of Concern, Pollutant Sources and Priority Ranking

- TMDL's are being submitted for two segments of the Androscoggin River on Maine's 303d list that do not attain water quality standards for class C.
- Gulf Island Pond does not attain class C minimum and 30-day average dissolved oxygen criteria in a four-mile segment directly above Gulf Island dam primarily in deeper areas of the water column from 30 to 80 feet of depth. In addition, algae blooms occur from excessive amounts of phosphorus discharged to the river flowing into the pond preventing attainment of the designated uses of water contact recreation.
- The Livermore Falls impoundment does not attain class C aquatic life criteria.
- The pollutants of concern are carbonaceous biochemical oxygen demand (BOD), ortho-phosphorus (ortho-P), total phosphorus (total-P), and, total suspended solids (TSS).
- Reduction of phosphorus is needed to eliminate algae blooms in Gulf Island Pond. Reduction of carbonaceous BOD, TSS, and phosphorus, is needed to improve dissolved oxygen levels to attainment of class C criteria. In addition, an instream oxygen injection system currently located five miles above Gulf Island Dam needs to be re-designed to provide additional amounts of oxygen in other areas of the pond.
- TSS and algae contribute to sediment oxygen demand, a major source of oxygen depletion in the deeper areas of Gulf Island Pond. TSS also is the major cause of non-attainment of class C aquatic life criteria in the Livermore Falls impoundment.
- Paper mills located in Berlin, NH; Rumford, ME; and Jay, ME are the major source of most of the pollutants. Municipal point sources are located in Berlin, NH; Gorham, NH; Bethel, ME; Rumford-Mexico, ME; and Livermore Falls, ME. Livermore Falls is a significant source of ortho-P. All municipal point sources are included in the TMDL.
- Gulf Island Dam contributes to non-attainment of DO criteria and the growth of algae blooms by creating an environment of low water movement and low vertical mixing within the water column. Non-attainment of class C DO criteria in deeper portions of the pond is predicted by the water quality model even if point source discharges are eliminated.
- The priority ranking of the TMDL was high with a completion date scheduled for 2003. The schedule was delayed one year to obtain additional data in the summer of 2004 to improve model predictions under reduced paper mill phosphorus loading.

Description of the Applicable Water Quality Standards and Numeric Water Quality Target

- Dissolved Oxygen – Class C numeric criteria require a daily minimum dissolved oxygen of 5 parts per million (ppm) and 60% of saturation. Narrative criteria require that waters shall be of sufficient quality to support all indigenous fish species. Cold water fish are indigenous to the Androscoggin River. EPA guidance specifies that a 30-day average dissolved oxygen of 6.5 ppm is needed to support growth of salmonid species of fish. Maine law states that dissolved oxygen readings below a point 0.5 meters from the bottom of the pond and below the point of thermal stratification should not be considered in a compliance evaluation for dissolved oxygen.

- Narrative class C criteria require that waters be suitable for designated uses of water contact recreation. Algae blooms result in unsuitable aesthetic conditions for swimming. Reducing the pond-averaged chlorophyll-a level to less than 10 ppb is the water quality goal established to eliminate algae blooms in Gulf Island Pond (see page 5).
- Narrative class C criteria specified for aquatic life (MRSA Title 38, Sect 465, 4C) state that "discharges to class C waters may cause some changes to aquatic life, provided that the receiving waters be of sufficient quality to support all species of fish indigenous to the receiving water and maintain the structure and function of the resident biological community." Macro-invertebrate sampling and a linear discriminate model are used to determine attainment / non-attainment status of narrative aquatic life criteria.

Loading Capacity – Linking Water Quality and Pollutant Sources
The following data, modeling reports, and responses to public comment are used for the scientific basis and public participation requirements of the TMDL

- Responses to Comments Draft Androscoggin River Modeling Report (Nov 2001)
- Androscoggin River Modeling Report and Alternative Analysis (MDEP, June 2002).
- Responses to Comments Final Androscoggin River Modeling Report (Sept 2002)
- Responses to Comments Androscoggin River and Gulf Island Pond Data Report (Jan 2005).
- Androscoggin River and Gulf Island Pond Data Report (Final, MDEP, Jan 2005).
- Androscoggin River Total Maximum Daily Load of Gulf Island Pond and Livermore Falls Impoundment, (Final, MDEP, March 2005)
- Responses to Comments of the Draft TMDL, March 2005.

Load Allocations and Waste Load Allocations

- The following is a summary of the TMDL for Gulf Island Pond expressed as loads to the entrance of the pond:

TMDL for Gulf Island Pond in PPD								
Required Loads in ppd		Total-P	Ortho-P	CBODu		TSS	Oxygen Injection Loads	
Averaging Period		30-Day	30-Day	30-Day	7-Day	Annual	U. Narrows	L.Narrows
Season		June-Sept	June-Sept	June-Sept	June-Sept	Year	June-Sept	June-Sept
WLA	Point Sources	208	45	39,818	45,673	42,093	30,000	150,000
LA	Non-Point Sources	77.7	0.3	10,440	9,444	47,907		
Explicit MOS 10%		31.7	5	5,585	6,124	10,000		
Total		317	50	55,843	61,241	100,000		

1. Instream aeration is needed as a component of the TMDL load due to sediment oxygen demand . There are no feasible reductions of WLA's and LA's that will result in full attainment of DO criteria without oxygen injection.

2. Oxygen Injection loads of 30,000 ppd at Upper Narrows and 150,000 ppd at Lower Narrows are the default requirements. Other systems are possible. See pages 27 to 51.

3. Oxygen injection loads of 50,000 ppd at Upper Narrows, 65,000 ppd at Lower Narows, and 42,000 ppd near the Deep Hole were investigated with a 3 point injection system.

4. All calculations assume a 1/3 transfer efficiency. Other systems other than those in this report may be acceptable provided they are approved by DEP.

5. Ambient monitoring is required and implemented in licensing.

- The averaging periods used for various pollutant parameters in the TMDL deviate from the default averaging period of one day. TMDL guidance indicates that it is acceptable for the averaging period for TMDL's to deviate from one day provided that justification is given for alternate averaging periods. Justification for the alternate averaging periods is explained in the text of this report (see pages 14, 30, 33, 53, and 56).
- The load allocations in the submitted TMDL's reflect current conditions and imply that there are no additional allocations for future increases of non-point source pollution.
- There are other combinations of total-P and ortho-P that result in acceptable TMDL's. These other combinations vary the total-P and ortho-P; as ortho-P is increased, total-P must be reduced (see page 20).
- Fraser Paper is limited by water quality on the discharge of BOD5 (five-day biochemical oxygen demand) to 11500 ppd as a weekly average as a result of the requirement to maintain class B minimum daily DO criteria of 7 ppm from the NH border to the confluence of the Ellis River (see page 30).
- The following is a summary of the TMDL for the Livermore Falls Impoundment expressed as loads to the entrance of the impoundment.

TSS TMDL For Livermore Falls Impoundment in PPD		
Averaging Period		60-Day
Season		June-Sept
WLA	Point Sources	24420
LA	Non-Point Sources	7800
Explicit Margin of Safety 10%		3580
Total		35800

1. Ambient monitoring of aquatic life is required and will be implemented in licensing.

2. Hydrologic flushing of the Livermore Falls impoundment should be investigated.

- Default waste load allocation of each TMDL for each point source is included in the text of this report in the following locations:
  Total-P and Ortho-P for Gulf Island Pond as a 30-day average page 26
  CBODu for Gulf Island Pond as a 7-day average page 32
  CBODu for Gulf Island Pond as a 30-day average page 34
  TSS for Gulf Island Pond as an annual average page 54
  TSS for Livermore Falls Impoundment as a 60-day average page 58

- There are many other possible ways to allocate point source loads. Examples of alternate allocations are presented also on the pages list above.

- Pollution trading can be considered by point source discharges for phosphorus and TSS using these trading ratios. In addition, regulatory agencies can consider different allocations from the default and alternate allocations in the licensing process using these trading ratios. No trading opportunity has been established for CBODU.

Table 5 - Trading Ratios for Phosphorus

Trading Rules
U=Upstream Point Source
D= Downstream Point Source
T= Ratio stated in table for U vs D.
D gains 1 ppd for T ppd that U gives up.
U gains T ppd for 1 ppd that D gives up.

Ortho-P	Fraser	Mead	IP	Livermore Falls
Fraser		8.1	57.4	57.9
Mead	8.1		7.1	7.1
Int. Paper	57.4	7.1		1.0
Livermore Falls	57.9	7.1	1.0	

Organic-P	Fraser	Mead	IP	Livermore Falls
Fraser		1.3	1.5	1.5
Mead	1.3		1.1	1.2
IP	1.5	1.1		1.0
Livermore Falls	1.5	1.2	1.0	

Note: Trading ratios are derived from the ratios of % of phosphorus remaining at Twin Bridges.

Table 14 - Trading Ratios for TSS

Trading Rules
U=Upstream Point Source
D= Downstream Point Source
T= Ratio stated in table for U vs D.
D gains 1 ppd for T ppd that U gives up.
U gains T ppd for 1 ppd that D gives up.

TSS	Fraser	Mead	IP
Fraser		1.5	2
Mead	1.5		1.33
International Paper	2.0	1.33	

Note: Trading ratios are derived from the ratios of % TSS remaining at Liv. Falls.

- Trading Conditions – Pollution Trading or revised allocation scenarios will be allowed as long as there are safeguards to ensure that the revised allocations do not cause localized water quality impacts ("hot spots"), must ensure the revised WLA for each pollutant specific TMDL will be satisfied, and that there is some opportunity for public review/comment on the revised allocations (such as the MEPDES permit process). These changes in the TMDL can be made without modifying and resubmitting a revised TMDL as long as the new allocation results in equal or greater water quality improvements as defined by the use of the trading ratios summarized in the tables above.

Margin of Safety

TMDL's must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between pollutant loads and water quality. EPA guidance explains that the MOS may be implicit, i.e. incorporated into the conservative assumptions used in the analysis, or explicit, i.e. expressed in loading set aside as a separate component of the TMDL. In this case an explicit margin of safety of 10% of the total TMDL was assigned to the total TMDL for all pollutants.

The 10% explicit margin of safety is based on the Department's best professional judgment to account for any lack of knowledge concerning the relationship between pollutant loads and water quality in the Androscoggin River. ME DEP has been monitoring the Androscoggin River since the 1960's, modeling the river since the early to mid-1980s, and working on additional monitoring and modeling intensively for the past five years in final preparation for this TMDL report. Based on the Department's experience, a 10% MOS is deemed to be sufficient. Although not part of the MOS, the Department is also recommending that ambient monitoring by dischargers should be undertaken for a minimum of five years with particular focus on sediment oxygen demand rates during the phased implementation of the TMDLs (see sections on monitoring and implementation plans). If necessary, this monitoring may be used to make further adjustments to the TMDL.

Seasonal Variation

Seasonal variations established for the summer and non-summer have been included in the TMDL. The dissolved oxygen non-attainment is limited to the summer period and hence the TMDLs for CBODu are limited to the summer (June-September). Oxygen injection requirements are also limited to the summer (June-September).

Algae blooms are also a summer water quality issue and, consequently the TMDL for phosphorus is limited from June to September.

The TSS TMDL for preventing high sediment oxygen demand is an annual issue which results in the implementation of the TMDL as an annual average. The TSS to prevent aquatic life non-attainment of the Livermore Falls impoundment is a summer issue resulting in the TMDL specified from June to September. Since the duration of macro-invertebrate sampling time is 60 days, the averaging time used for loads is 60 days.

Implementation of TMDL

Implementation will be a phased approach involving stepped reductions with monitoring end points. There is some uncertainty in water quality modeling and the assignment of various parameter rates. In addition, there is uncertainty involved in the determination of the water quality target of chlorophyll-a levels used to describe the threshold level of an algae bloom that are specific to Gulf Island Pond. In the interim, established literature values for the chlorophyll-a threshold are being used. The goal of establishing the water quality threshold goal using 2004 water quality data was difficult as critical conditions of low flow and high water temperatures were not reached. As such additional ambient monitoring of the pond will likely add confidence to the estimate of the present chlorophyll-a threshold that is specific to Gulf Island Pond.

For this reason, it is recommended that the TMDL be implemented in phases of two or three step reductions with required ambient monitoring for point sources in cooperation with MDEP. The step reductions are an important component of the phosphorus TMDL, which could result in end points that are difficult for point source discharges to achieve. MDEP recognizes that the TMDL limits for phosphorus translate into very significant phosphorus reductions for certain point source discharges. The TMDL could be changed, if appropriate, as more data are collected under reduced phosphorus loading to the pond. Monitoring for compliance of aquatic life criteria in the Livermore Falls impoundment is necessary every summer until a better relationship can be established between TSS loading and seasonal regulated flow.

The WLA reductions and oxygen injection requirements will be implemented through NPDES permitting and a water quality certification for the Gulf Island-Dam Hydropower licensing.   Default allocations for point sources are provided in the text. Other allocations are possible for TSS and phosphorus and can be readily calculated in spreadsheet format with the assimilation factors and the trading ratios provided in the text. Adjustments from the default WLA's will be subject to public notice and comment in the NPDES permit issuance process and must ensure that the total WLA for each TMDL will be satisfied and that there will be no localized impacts.

The following information should be considered in the hydropower re-licensing of Gulf Island dam for the implementation of the TMDL.

- Modeling has indicated that 65,000 ppd oxygen injection at Lower Narrows or 105,000 ppd at Upper Narrows at a transfer efficiency of 33% is needed to comply with class C DO criteria with all point sources removed.
- Modeling also indicates that the presence of the dam accounts for about 20% of the algae levels in Gulf Island Pond with the TMDL implemented.

Reasonable Assurances

Reasonable assurances are required when point sources are given a less stringent waste load allocation based upon an assumption that non-point source reductions or non-treatment alternatives will be used in lieu of point source reductions. There are no reductions of non-point source pollution being required in the TMDL's being submitted for the Androscoggin River. However in-stream aeration is required for Gulf Island Pond and results in less stringent WLA's for CBODu as a 7 and 30 day average and TSS as an annual average. There is a reasonable assurance that the instream oxygen injection will occur, since it is being required through waste discharge licensing and the water quality certificate for Gulf Island dam. The demonstration that is required by using non-treatment alternatives in lieu of treatment alternatives (40 C.F.R. 125.3 (f)) will be submitted for DEP review prior to licensing and the submittal of the TMDL.

Monitoring Plan for TMDL

The initial monitoring plan will follow the format of the 2004 summer sampling within Gulf Island Pond. Weekly sampling from June to September at five locations (Twin Bridges, Upper and Lower Narrows, GIP4, Deep Hole) for chlorophyll-a, total and ortho-

P, DO, temperature, and secchi depth. Any changes to the 2004 plan should be submitted to DEP for approval 60 days prior to the beginning of sampling in any given year. International Paper will submit a plan for annual macroinvertebrate monitoring in the Livermore Falls impoundment along with daily flow records.

The continuous monitoring for DO/temperature should be changed from the current monitoring so that a depth of 60 feet near the dam is monitored. This is the most difficult location for meeting compliance of DO criteria within the pond.

If the end points are reached before the final TMDL is realized, a new TMDL will be submitted to EPA for approval. The monitoring end points are as follows:

<u>Monitoring End Point of Phased Implementation of TMDL</u> results when two summers of monitoring occurs without algae blooms, and aquatic life criteria are maintained when

- Simultaneously both the river flow at Rumford < 2000 cfs and river temperature at Turner Bridge > 24^{o}C for a minimum of thirty consecutive days in each given summer. A flow of 2000 cfs is approximately 15% higher than 30Q10. The new TMDL is set 15% less than lowest loading entering the pond during the two monitoring events or can be determined by modeling.

Or when one summer of monitoring occurs without algae blooms, and aquatic life criteria are maintained when

- Both the river flow at Rumford < 1740 cfs and river temperature at Turner Bridge > 24^{o}C for a minimum of thirty consecutive days for one given summer. A flow of 1740 cfs is the 30Q10 flow at Rumford. The new TMDL is set at actual loading conditions entering the pond at the 30Q10 event or can be determined by modeling.
- The monitoring end point for dissolved oxygen compliance results when five years of monitoring occurs with complete compliance of all DO criteria. The river flow should be within 15% of 10 year low flow with the 30-day average temperature approaching 22^{o}C and the 7-day average temperature approaching 26 ^{o}C at Turner in a minimum of one of the five years.

The end point can be reached for parameters individually while abatement continues for other parameters. The ambient monitoring should be undertaken for five years.

Public Participation

There were public meetings in Lewiston and Rumford in December of 2004 to obtain public input to the TMDL. In both the modeling report of 2002 and data report of 2004 public comment was sought prior to issuance of a final report. DEP hosted a number of stakeholder meetings in 2003 to 2004 pertaining to modeling, data collection, and general stakeholder comments. This report will be advertised in local newspapers from Berlin to Lewiston. There were extensive written comments to the draft TMDL issued in January of 2005. The public meetings and written comments resulted in a number of significant changes in the TMDL such as

- Re-allocations of phosphorus and TSS are presented.
- The MOS is quantified explicitly as 10% of the total TMDL.

- Established default allocations for phosphorus, TSS, and CBODu and a default oxygen injection requirement.
- Removed conservative assumption of all point sources discharging their maximum loads simultaneously
- Tables 4, 5, 6, 8, 9, 10, 13, and 14 were re-done and text were added to better explain the allocation methods, assimilation of phosphorus and trading ratios of phosphorus and TSS.
- A method of implementation is presented for paper mills to give the option of a summer daily maximum BOD5 mass limit rather than a summer weekly average mass BOD5 limit.
- Followed recommendation to limit implementation of phosphorus TMDL from June to September rather than May to September.
- Followed recommendation to allow small or insignificant municipal inputs to implement phosphorus TMDL as "monitor only" in the initial phase with periodic re-evaluations.
- Added additional model prediction runs utilizing additional oxygen injection requirements assuming the same injection rates as current at Upper Narrows for the TMDL loads and zero discharge of point source loads.
- Defined a monitoring end point when compliance of water quality standards is reached.
- Added additional explanation of required monitoring in TMDL.
- Added clarification of reason oxygen injection must be included in the TMDL.
- Additional clarification and re-wording of text for the Dead River issue.[1]

[1] The Dead River is a tributary of the Androscoggin River with water quality issues relating to algae blooms and non-attainment of dissolved oxygen criteria. These problems have just recently been discovered and the Dead River is not yet 303d listed. Issues on the Dead River will be addressed in a separate water quality analysis in the future. More specific information is discussed in the last section of this report.

Determining the TMDL – Additional Model Analysis

Introduction

The Androscoggin River has had a long history of very poor water quality. A low point was reached in the 1960's when it was recognized as one of the ten most polluted rivers nationally. Considerable cleanup progress has been accomplished over the years up to a point where water quality standards are met along the length of the river except in portions of a deep impoundment called Gulf Island Pond and a smaller impoundment at Livermore Falls.

The water quality classification of the Androscoggin River is class B from the Maine / New Hampshire border to the confluence of the Ellis River and class C in its entire downstream length. Both Gulf Island Pond and the Livermore Falls impoundment are classified as C. This is the lowest legal classification, but both state and federal law still require class C river segments to meet a fishable and swimmable standards.

Gulf Island dam is located in Lewiston-Auburn and impounds the Androscoggin River for a distance of 14.5 miles up to the towns of Greene and Leeds on its east bank and Turner on its west bank. Gulf Island Pond has a mean depth of 21 feet and maximum depth of 80 feet at its deep hole located approximately 1500 feet upstream from the dam.

Upriver from Gulf Island Pond, numerous point sources that discharge to the Androscoggin River influence the pond's water quality. Paper mills discharge to the river in Berlin, NH (Fraser Paper), Rumford, ME (Mead WestVaco), and Jay, ME (International Paper). Municipal point sources are located in New Hampshire (Berlin and Gorham) and in Maine (Bethel, Rumford-Mexico, and Livermore Falls). The collective dilution of the river 7-day 10-year low flow (7Q10 flow) to all point source discharges above Gulf Island Pond is only 8.6:1. The low dilution that is available for point source discharges and the poor capacity provided by the pond to assimilate wastes both result in a difficult situation for maintaining adequate water quality. Sources of non-point source pollution include land use activities related primarily to residential development, silviculture, and agriculture. There are limited opportunities for the control of significant amounts of non-point source pollution given the relatively undeveloped nature of this large watershed.

The lower four miles of Gulf Island Pond are on Maine's list of waterbodies that do not attain their water quality classifications ("303d list"). Class C dissolved oxygen criteria currently require that levels be maintained at a minimum of 5 ppm and 60% of saturation and a monthly average of 6.5 ppm. The lower four miles of Gulf Island Pond frequently do not attain either of the dissolved oxygen criteria in the summer at depths of 30 to 80 feet.

Narrative class C criteria require that water bodies be suitable for designated uses of water contact recreation. Algae blooms result in undesirable aesthetic conditions for water contact recreation. Algae blooms that develop on the pond every summer must be addressed to bring the pond into attainment status. Narrative class C criteria specified for aquatic life state that "discharges to class C waters may cause some changes to aquatic life, provided that the receiving waters be of sufficient quality to support all species of fish indigenous to the receiving water and maintain the structure and function of the resident biological community." Water quality evaluations utilizing macroinvertebrate sampling and the use of a linear discriminate model indicate that the Livermore Falls impoundment fails to meet class C aquatic life criteria.

As a result of being on the 303d list, the Federal Clean Water Act requires that a Total Maximum Daily Load[2] (TMDL) be developed to bring this water body into compliance with class C water quality standards. This TMDL has a high level of priority on the 303d list with a projected completion date at the end of 2003. Sampling undertaken in the summer of 2004 to improve water quality model predictions has delayed the completion of the TMDL until the end of 2004.

Much effort has gone into monitoring and modeling water quality on the Androscoggin River and Gulf Island Pond by DEP, paper mill personnel, and various citizen volunteers. A water quality model[3] was originally set up for the river and pond by DEP and paper mill consultants in the early to mid 1980's from data collected primarily in 1982 and 1984. The water quality model predicted that no level of pollutant abatement could result in full attainment of dissolved oxygen criteria everywhere in Gulf Island pond, due to a large accumulation of organic waste (sediment oxygen demand) on the bottom of the pond from historic sources of pollution.

As a result an in-stream oxygen diffuser was installed in the pond in 1992 approximately five miles up from the dam in a location called Upper Narrows, one of two hydrologic constrictions located on the pond. A cooperative agreement was reached between the three paper mills and a public utility company (now FPL Energy) that owns the dam and its hydropower generating facility. The aeration system became known as Gulf Island Pond Oxygenation Project (GIPOP). After the aeration system was installed in the summer of 1992, immediate improvements in dissolved oxygen in the pond became evident.

In 1990, legislation was enacted requiring color reductions in paper mills. This resulted in improved water clarity, but also contributed to increased problems with algae blooms within Gulf Island Pond. There is some evidence in the data collected prior to 1990 that

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[2] A TMDL is a plan of action for cleanup of a water body that currently doesn't meet water quality standards, which should result in a reasonable assurance that criteria will be met after implementation of the plan. The plan typically involves reductions of point and/or non-point sources of pollution and includes an adequate margin of safety related to the degree of uncertainty in the scientific analysis.

[3] A water quality model uses complex mathematics to simulate water quality conditions in a river or pond. The complexity of the math results in the use of computer software. Models are used to predict worse case water quality of such parameters as dissolved oxygen and algae levels as they related to pollutant loading, river flow, and temperature. Assumptions used in models are calibrated by actual field data.

blooms occurred within the pond. Algae growth and the development of blooms were generally lower then because highly colored water limits light penetration within the water column, and so limits algae growth.

A number of waste treatment improvements have been realized at the paper mills as a result of voluntary pollution prevention efforts and regulatory requirements. Gulf Island Pond has been monitored closely since 1992 to document the improvements in water quality. As expected, the data have initially shown significant improvements in dissolved oxygen levels in Gulf Island Pond in 1992, but little improvement since 1992. Some non-attainment of class C dissolved oxygen criteria persist every summer in the deeper portions of the pond.

In 1999 and 2000 additional data were collected on Gulf Island Pond to update the water quality model to current conditions. The new data indicated that algae blooms have become a significant problem. This was not addressed in the earlier modeling. The causes of the persistent non-attainment of dissolved oxygen criteria and algae blooms in the pond and possible solutions were discussed in the Androscoggin River Modeling Report and Alternative Analysis prepared by MDEP in June of 2002. The report was originally released as a draft in June of 2001. After an extensive review process by stakeholders, a number of changes were made. The model was re-calibrated and the report became final in June of 2002.

Some of the significant findings of the 2002 report are as follows:

- Sediment oxygen demand (SOD) is the largest source of dissolved oxygen depletion in the deeper areas of the pond.
- The majority of SOD is derived from the settling and decay of algae.
- Non-point and natural sources account for about ½ of the current SOD and point sources the other ½.
- The operational modes of hydropower generation (store and release) do not appear to be negatively affecting dissolved oxygen levels.
- Point source discharges and the existence of a large impoundment (Gulf Island Pond) below point source discharges are the primary cause of algae blooms.
- Paper mills account for the majority of phosphorus and biochemical oxygen demand (BOD)[4] inputs to the pond.
- With no oxygen injection and the complete removal of point source discharges, some non-attainment of DO criteria could still result due to the poor mixing characteristics of the pond and sediment oxygen demand from the presence of the dam.

The 2002 water quality model was run in the prediction mode to determine possible solutions for improving the pond to class C standards. Reduced point source loading of BOD, phosphorus, and suspended solids and additional oxygen injection were investigated. The model prediction runs suggested that additional oxygen injection and large reductions of phosphorus from point sources were needed.

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[4] Biochemical Oxygen Demand (BOD) is measured by a laboratory test estimating the amount of oxygen demanding substances in water samples. Oxygen depletion of a water sample is measured over a time increment and often a first order reaction rate is fitted to the data.

The 2002 modeling effort suggested that attaining DO criteria solely through point source reductions is difficult. Even if point sources are reduced by 90% from current discharge levels, the model predicted some non-attainment is likely to occur in the very deep segments. As such, the in-stream aeration diffuser is a much more efficient and reliable way to meet DO criteria.

The 2002 model also predicted that it would be difficult to meet DO criteria with the current system involving only one injection point five miles upstream of the dam at a depth of 30 feet. About two miles below the current injection site is the Lower Narrows where the depth of the pond increases rapidly to a depth of 50 feet. The depth eventually reaches 80 feet at the deep hole above the dam. It is difficult for the oxygen injected at a 30-foot depth to reach the deeper areas of the pond located below Lower Narrows. The model predictions indicate that an additional injection point at Lower Narrows or other locations or a redesigned system is needed. The GIPOP consortium has sponsored an evaluation of the present oxygenation system that has been submitted to the Department for evaluation at the end of 2004. This report provides information useful for implementation of the TMDL.

A data collection effort in the summer of 2004 involved sampling of both the river and the pond under reduced phosphorus discharge conditions. A goal involving the use of these data was to make the predictions of the water quality model more reliable. Both the sampling of the river and pond and the phosphorus reductions were voluntary efforts undertaken by the three paper mills. DEP and other citizen volunteers assisted in the river sampling. The data collected in the summer of 2004 provided model calibration data sets under reduced phosphorus loading and targeted some of the data deficiencies identified in the 2002 modeling effort. This results in greater confidence of model predictions under reduced phosphorus loading to the pond.

Summer 2004 Data

A detailed description of the data collection effort in the summer of 2004 can be obtained from the Androscoggin River and Gulf Island Pond Data Report (DEP, January 2005). The study involved weekly sampling of the Androscoggin River from Berlin, NH to Turner, ME at eight locations and five additional locations in Gulf Island Pond. The three paper mills on the Androscoggin were undergoing voluntary phosphorus reductions of their waste discharge. This resulted in measured total phosphorus and ortho-phosphorus levels entering Gulf Island Pond that were 38% and 70% lower, respectively, than levels measured in the summer of 2000.

A summary of some of the findings were as follows:

- The summer of 2004 was wet and cool and not ideal for judging critical water quality conditions that are ordinarily experienced in dry and warm summers. The highest 30-day average temperature experienced in 2004 was 2 ^{o}C lower than warm summers. Many runoff events occurred in 2004. In dry summers no runoff can occur for several weeks.

- All dissolved oxygen criteria were maintained in the river from Bethel to Twin Bridges (Rte 219) in Turner.
- Minimum DO criteria and 30-day average DO criteria were not met in the deeper portions of the lower three miles of Gulf Island Pond for a minimum of 68 and 39 days, respectively.
- On Gulf Island Pond widespread algae blooms were observed on only 1 of the 12 sampling days. Blooms of a localized nature occurred on three additional sampling days.
- A consistent relationship of peak chlorophyll-a [5]readings and observed algae blooms was not apparent in the data on Gulf Island Pond. However there does appear to be a good relationship to observed blooms and pond averaged chlorophyll-a.
- Water quality trends are difficult to describe with only one summer of data under reduced phosphorus loading. Best professional judgement indicates that algae blooms can be expected to be less severe and frequent with the lower ambient phosphorus levels. There does not appear to be any improvement or diminishment in the pond dissolved oxygen since 1998.

A major goal of the 2004 sampling effort was to better define the chlorophyll-a threshold levels for algae blooms specific to Gulf Island Pond. This was difficult due to the fact that only one major bloom was observed all summer. In the past DEP has used a range of 8 to 12 ppb as a threshold to define algae blooms which is consistent with literature values (Nutrient Criteria Technical Guidance Manual for Rivers and Streams, USEPA, July 2000). Both literature values and the 2004 data will be used to define an interim threshold that will be used in the TMDL. The chlorophyll-a threshold for defining an algae bloom should be re-evaluated yearly with data that will be collected in the future with a goal of refining the threshold specific to Gulf Island Pond.

The plot of Gulf Island Pond chlorophyll-a is repeated from the data report (Figure 1). The only date in which a widespread algae bloom was observed in 2004 on Gulf Island Pond was August 4. The bloom was observed from Lower Narrows to the Deep Hole. If pond averaged chlorophyll-a data are used as the threshold metric, a good relationship is apparent in the chlorophyll-a data and observed blooms. The pond-averaged chlorophyll-a of 10 ppb occurring on August 4 was also the highest pond averaged value measured all summer. The only other date approaching this was June 23. Although a bloom was not observed on this date, the pond may have been very close to a bloom condition and perhaps the cooler water temperatures may have prevented the bloom from occurring. Hence it would appear that when the pond averaged values from Turner Bridge to the Deep Hole approach 10 ppb, this is when blooms could occur. A chlorophyll-a threshold of 10 ppb is also the middle of the range DEP has used in the past for defining an algae

[5] The chlorophyll-a test reported in parts per billion (ppb) is used as an indicator to quantify the amount of phytoplankton or floating algae within a water sample.

bloom. This will be the threshold established in the TMDL for preventing algae blooms based upon the best available information; the threshold may be adjusted in the future if warranted by new information. Some other goals of the 2004 sampling effort were to better define phosphorus assimilation rates in the Androscoggin River, and to obtain calibration data sets for Gulf Island Pond under reduced phosphorus loading so that the algae component of this model could better predict algae levels. In addition, updated effluent phosphorus data were obtained for municipal point sources and paper mills practicing phosphorus pollution prevention.

Water Quality Model Calibration and Changes from 2002 Effort

Data considered most useful for model calibration are low flow and high water temperature periods with no significant runoff prior to and during the sampling. For the summer of 2004 this was difficult due to the numerous runoff events that occurred throughout the summer. An average of four consecutive sampling days was used as a model calibration data set, which resulted in a three week averaging period. The sampling periods in 2004, considered most useful for model calibration were from June 16 to July 7 and July 21 to August 11 (Figure 2). The large runoff events occurring prior to each period result in conditions not considered ideal, but the best that was available for the summer of 2004.

A deficiency identified in the 2002 model was the lack of recent ambient phosphorus data in the Androscoggin River for calibrating assimilation of ortho-phosphorus (ortho-P) and organic-P (OP). An ortho-P assimilation (loss) rate was calibrated from data collected in 1982 and 1984 under high phosphorus loading conditions from paper mills. The loss of phosphorus is mostly from bottom-attached plants and algae in the river, which utilize primarily ortho-P for their growth. As phosphorus loading is reduced, the population of bottom-attached plant should be reduced so ortho-P uptake should also be reduced, compared to conditions in 1982 and 1984.

The use of accurate phosphorus uptake rates is critical for establishing license limits for each point source discharge. Most of the phosphorus assimilated in the Androscoggin River from Berlin to Turner will not be available to contribute to algae blooms in Gulf Island Pond. If assimilation of phosphorus is significant, point sources such as the NH discharges that are distant from the pond may contribute very little to the pond's algae blooms.

The phosphorus uptake rates assigned to the river will not influence the overall TMDL of Gulf Island Pond expressed as a load to the pond. The phosphorus TMDL to the pond will be established through trial and error model prediction runs by varying the pond boundary of ortho-P and OP in the WASP[6] model. When allocating the waste loads to point sources, the phosphorus uptake rate assigned to the model becomes important. The

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[6] WASP and Qual2EU are computer modeling software packages used in simulating water quality in Gulf Island Pond and the Androscoggin River above the pond, respectively. A description of WASP and Qual2EU can be found in the 2002 Modeling Report.

river model (Qual2EU) was run independently of the pond model to determine the percentage of phosphorus loads assimilated in the river. Since the 2004 data did not include chlorophyll-a in the Androscoggin River from Berlin to Bethel, it was not possible to simulate algae and periphyton (bottom attached plants). Total phosphorus and ortho-phosphorus were sampled at all river locations. As a result, a separate Qual2EU model was created dedicated only to OP and ortho-P assimilation. Both were modeled as first order reaction rates similar to BOD decay. This method included phosphorus lost through settling and phytoplankton growth so all known loss terms for phosphorus are included. Table 1 summarizes all model parameters that have been changed between the 2002 and 2004 model runs of Qual2EU and WASP for the Androscoggin River, and Gulf Island Pond.

Table 1 Changes from 2002 Model Parameter Rates and Constants

Qual2EU	Units	Constant or Variable by Model Reach?	2004 Rate	2002 Rate	Comment
OP Loss Term	/day	Constant	0.05	0.05	Rate for 2004 includes all loss terms. 2002 Model is OP mineralization only.
BOD Removal	/day	Constant	0.2	0.2	No settling term in 2002 model is unrealistic. Setling term applied to 2004 model based upon particulate BOD data from 2001 (see p45, 2002 Modeling Report).
BOD Decay			0.165	0.2	
BOD Settling			0.035	0	
Ortho-P Loss Term	/day	Variable	Rate		Ortho-P uptake modeled as negative flux in 2002 model. 2004 effort models uptake as first order reaction rate. Higher uptake rate assigned to shallower free-flowing segments and below point source discharges where P-concentrations are higher.
		Model Reaches 1-3	2.3		
		4-8	0.1		
		9	3.5		
		10-11	1		
		12	0.3		
		13-16	0.01		

WASP	Units	Constant or Variable by Model Reach?	2004 Rate	2002 Rate	Comment
P-Half Saturation Constant	mg/l	Constant	0.002	0.001	New rate results in improved calibration.
Dissolved Fraction DIP	unitless	Constant	1	0.5	New rates for CBOD and OP assigned as data suggest. DIP as literature default suggests.
Dissolved Fraction OP	unitless	Constant	0.42	0.1	
Dissolved Fraction CBOD	unitless	Constant	0.8	0.5	
Frac Dead Algae Recycled to OP	unitless	Constant	0.5 / 0.7	0.9	HydroQual 0.5. DEP 0.5 to 0.7. 0.5 used for Prediction
OP Mineralization Rate	/day	Constant	0.02 / 0.05	0.05	DEP 0.05. HydroQual 0.02. 0.05 used for Prediction.
Settling Velocity PO4-P	m / day	Constant	0.5	0	Rate of 0 consistent with Dissolved Frac. DIP=0.
Saturated Light Intensity	Ly / day	Constant	175 / 300	175	175 consistent with literature default. HydroQual recommends 300.
BOD Decay	/day	Constant	.05 / .04 / .03		Different rates assigned for point Sources at License (.05), TMDL (.04), and zero discharge (0.03)
Sediment PO4-P Flux	mg / m^2-day	Variable	3	0.75	Followed HydroQual recommendation

Sediment Oxygen Demand	Variable by reach and discharge conditions		Model Reach Bottom Segments			Rates assigned in 2004 consistent with methodology discussed and rates assigned in 2002 modeling report. Rates assigned to surface and subsurface segments according to ratio of additional bottom area.
			1-7, 10	13,16,19,24,30	36,43	
Point Sources at License	gm / m^2-day	Variable	2.17	2.92	2.02	
TMDL Implemented	gm / m^2-day	Variable	1.74	2.26	1.32	
Point Sources = 0.	gm / m^2-day	Variable	1.05	1.21	0.7	

The rapid loss of ortho-P in the 2004 ambient data in the river from Berlin and to Jay implies a high ortho-P assimilation rate. The ortho-P appears to remain nearly constant from Jay to Turner implying a low ortho-P assimilation rate. The difference is likely because the Androscoggin River is shallower and more free-flowing from Berlin to Jay as opposed to below Jay, which is impounded, and deep. The river from Jay to Turner contains the most color and TSS from the inputs of all three paper mills. The lack of light penetration to the river bottom from the greater turbidity and deeper depth is the primary factor influencing low bottom-attached plant growth and hence low ortho-P assimilation.

The shallower and less turbid water from Berlin to Jay is more suited to growth of bottom-attached plants which uptake ortho-P. MDEP's experience modeling ortho-P uptake in other rivers indicates that as ortho-P concentrations increase, the rate of assimilation of ortho-P also increases. Hence higher rates are assigned directly below point source discharges in free-flowing riverine sections. This results in rates as high as 2.3 and 3.5 /day, respectively in Berlin and Rumford but as low as 0.01 /day from Jay to Turner. The June 16 to July 7 data are used for model calibration of ortho-P uptake and the July 21 to August 11 for model verification of ortho-P uptake (Figures 3 and 4)[7]. A good fit is obtained for both data sets.

For the organic-P mineralization, rates of 0.02 and 0.05 /day were investigated. A rate of 0.02 /day was recommended by HydroQual (consultants to MeadWestVaco) as the OP mineralization rate[8] in Gulf Island Pond. MDEP used a rate of 0.05 /day for P-mineralization in the 2002 model in both the river and pond and recommends this rate is more appropriate than 0.02 per day. It is not possible to tell by curve fitting which rate result in a better fit of model to observed data. Either rate results in an acceptable fit (Figures 3 and 4). However literature values for OP mineralization suggest that 0.02 /day is on the very low end of values suggested, and 0.05 is most likely a more typical rate.

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[7] Model calibration refers to a match of model output for a water chemical parameter to actual data collected in the field for given assumptions of parameter rate model inputs. Model verification occurs when the same assumed model input rates results in a good match of model output to a second independent data set.

[8] The organic-P mineralization rate refers to the rate that OP converts to ortho-P. OP is calculated in the model as (total-P – ortho-P). The model assumes ortho-P is the only portion of total-P available for algae growth. When river travel times are sufficient, such as what occurs in Gulf Island Pond (up to two weeks), some portion of OP is likely available for algae growth. In quick flowing areas, usually only ortho-P is available for algae growth, since there is not sufficient time for OP to convert to ortho-P.

The Qual2EU user's manual suggests a range of 0.01 to 0.7 /day and TetraTech's Help and limit Screens for WASP4 suggests a default value of 0.22 /day. A range stated in the WASP6 user's manual suggests a range of 0.02 to 0.10 /day. A combination of the three literature sources cited for the OP mineralization rate suggest that a rate of 0.05 per day is more likely accurate for Gulf Island Pond than a rate of 0.02 per day. Additional justification for the adoption of the rate of 0.05 per day is discussed later in this report (pages 13 and 20).

The only other change in the Qual2EU model of the river was to BOD removal. The removal rate of 0.2 per day calibrated in the earlier modeling effort was not changed. However, the 2002 model did not include a settling component for BOD; all removal was assumed to occur through decay. The data collected in 2001 at Twin Bridges indicates that about 20% of the ultimate CBOD entering Gulf Island Pond is particulate BOD. Hence 20% of the BOD removal was assigned to settling.

In the Gulf Island Pond WASP model, the algae component of the model was re-calibrated to data collected in 2004 under reduced phosphorus input loading to the pond. In addition, model runs were made to data collected in August of 1998 and August of 2000. The 1998 data has the major disadvantage of no boundary data at Twin Bridges, so boundary concentrations similar to measured values at Turner Bridge have to be assumed. Both the 1998 and 2000 data also had the disadvantage of being collected in relatively wet summers involving undesirable runoff conditions.

MDEP was assisted in the 2004 model re-calibration of Gulf Island Pond by HydroQual, consultants to MeadWestvaco. This collaborative process has resulted in a model that is much better than the 2002 model. However there are still some areas of disagreement on the most appropriate rates for model predictions.

One of these already discussed is the appropriate rate for OP mineralization to ortho-P. It would appear from the literature that a rate as low as 0.02 /day is possible, but 0.05 may be more typical given the range of values discussed earlier in the text. Another parameter is for the saturated light intensity in which MDEP recommends a value of 175 langleys/day compared to HydroQual's recommendation of 300 langleys / day. Both are within the ranges specified in literature, but TetraTech's guidance manual for WASP suggests a default of 175.

When calibrating model predictions to field data, the modeler attempts to keep all of the parameter inputs the same for different independent data sets. Often the match is compromised if this procedure is rigidly followed. In reality, the rates do vary some for different environmental conditions, especially given the complexity of Gulf Island Pond. If too many of the rates are varied from one calibration data set to the next, the dilemma for the modeler is assigning the appropriate rates for the prediction runs which determine the TMDL. Hence, many modelers rigidly follow a calibration procedure in which the model parameter rates remain constant for all data sets.

To get as close a fit to observed conditions, DEP varied three key parameters that had the most relevance for model outputs. The model calibration for algae in Gulf Island Pond is plotted using the three considered parameter rate inputs as outlined below:

Table 2 - Summary of Parameter Rate Differences			
Model Run	OP Mineralization	Frac Dead Algae to OP	Saturated Light Intensity
DEP1	0.05	0.7	175
DEP2		0.5	
HydroQual	0.02	0.5	300

It is difficult to determine which set of rates is better solely by curve fitting (Figures 5 to 8). The differences in the model predictions are generally small when comparing the three calibrations in table 2. Therefore it is more critical to calibrate the chlorophyll-a level for the July 21 to Aug 11 data set accurately, for this determines the phosphorus TMDL because it encompasses the time period of the August 4 bloom. The DEP2 rates fit the measured chlorophyll-a levels in Gulf Island Pond better for this data set than HydroQual's rates which result in lower than observed chlorophyll-a at the locations experiencing the bloom. The DEP2 rates are also more consistent with literature default values suggested in the TetraTech guidance manual. The DEP2 rates are used in the model prediction runs for defining the TMDL, but all three rates are run and compared.

Phosphorus TMDL

The model predictions for chlorophyll-a in the three calibrations in Table 2 (DEP1, DEP2, HydroQual) are compared in Figure 9. The parameter rates used for DEP2 result in the highest prediction of chlorophyll-a, which will be used in establishing the TMDL. This results in a model prediction that is more probable as is discussed below in more detail.

The temperature and flow used in the phosphorus TMDL are consistent with that used in the 7-day ultimate carbonaceous BOD (CBODu) TMDL. The seven day ten-year low flow (7Q10) and 7-day average temperatures reflect the averaging period of seven days or the time that is likely for an algae bloom to develop. The 30-day averaging period for the TMDL is used as the averaging period to implement the license limits for phosphorus to point sources as a summer monthly average. Summer is the only season when algae bloom are a concern on the pond when the pond is poorly mixed vertically and water transported may be limited to the top layers of the pond.

A 30-day averaging period is used for point sources due to the long travel time of about three weeks for point sources discharges to be transported over the entire river area from Berlin to Gulf Island dam at 7Q10 conditions. Point sources collectively account for most of the algae bloom problems, and short term peaks of phosphorus from individual point sources are dampened through longitudinal dispersion. It is the longer term discharges of point source phosphorus that matter for the development of algae blooms and hence the 30-day averaging period for phosphorus. For an explanation of the 7Q10 flow and the rationale for assigning the 7-day average temperature, one should consult the section of this report explaining the 7-day CBODu TMDL.

The threshold for the phosphorus TMDL is to maintain the pond-averaged chlorophyll-a under 10 ppb. There are different combinations of total-P and ortho-P that could result in obtaining this goal. A summary of four possible phosphorus TMDL combinations is summarized in Table 3. It is worth noting that the model predictions of chlorophyll-a are not significantly different for each of the four possible TMDL options.

If the model is run with the rates recommended by HydroQual in prediction mode, the model predicts that ortho-P and total-P at the pond entrance should be regulated at 12 ppb and 42 ppb, respectively to prevent the pond averaged chlorophyll-a from exceeding 10 ppb. Ortho-P was in the range of 7 to 9 ppb and total-P was around 30 ppb at the pond entrance during the time of the algae bloom experienced on the pond during August 4, 2004. Therefore HydroQual's model outputs do not seem appropriate. It is not valid to regulate the pond at phosphorus levels that are higher than what was actually measured during bloom conditions.

Table 3 Gulf Island Pond Phosphorus TMDL as a 30-Day Average - Applies June to September

Option	Phosphorus concentration entering pond in ppb		TMDL in PPD	
	TP	Ortho-P	TP	Ortho-P
Default	34.6	5.5	317	50
2	34	6	312	55
3	32	7	293	64
4	30	8	275	73

*River 7Q10 flow of 1704 cfs entering the pond is used in load determinations.

As ortho-P is increased, organic-P must be decreased. The model runs indicate that for each ppb increase of ortho-P at the pond entrance, organic-P must be decreased by 3 ppb to maintain the pond averaged chlorophyll-a under 10 ppb. Paper mill personnel have indicated that ortho-P is easier to control rather than organic-P, since the former is ordinarily added to maintain adequate nutrient concentrations for waste treatment of BOD and TSS. For municipal discharges, phosphorus removal technologies ordinarily result in mostly ortho-P removal. For this reason, option 1 is established as the default phosphorus TMDL for Gulf Island Pond since it maximizes organic-P discharge which is the most difficult to remove in pollution prevention (P2) or waste treatment options. Obviously other combinations of total-P and ortho-P can result in attaining the pond averaged chlorophyll-a goal of under 10 ppb. Changes to the default may be made during the NPDES permit process, subject to public notice and comment and provided that the adjusted combination will result in attaining the goal referenced above.

The chlorophyll-a predicted by the model by implementing the phosphorus TMDL is compared to chlorophyll-a prior to the 2004 reductions of phosphorus by paper mills and chlorophyll-a with point sources at zero-discharge (Figure 9a). The model predicts that the pond chlorophyll-a would peak at 24 ppb and the pond averaged chlorophyll-a would be about 20 ppb. The highest phosphorus levels that were measured at the pond entrance in 1998 and 2000 were 30 ppb and 67 ppb for ortho-P and total-P, respectively. These levels were used as phosphorus inputs to simulate what would happen at worse case conditions of low flow and temperature. The summer of 1999 was a good example of worse case in which a 7Q10 flow was nearly reached. Using the same averaging method discussed, the highest pond averaged chlorophyll-a averaged over three weeks was 23 ppb that summer. This compares well with model predictions of worse case (chlorophyll-a = 20 ppb). Either of the other two calibration options investigated would lead to lower predictions of chlorophyll-a and poorer fits to the 1999 data. This is further justification for using the DEP2 calibration rates for the model prediction run.

The model prediction at zero-discharge of point sources is for chlorophyll-a to increase from its boundary level of 2.4 ppb at Twin Bridges to a pond averaged value of 4.5 ppb and eventually peaking at 7 ppb just above the dam. The incremental increase of chlorophyll-a from the boundary at Twin Bridges to the pond averaged chlorophyll-a is about 2 ppb or about 20% of the total threshold level established for bloom conditions (10 ppb). Thus it is reasonable to assume that the presence of the dam is responsible for about 20% of the algae levels in Gulf Island Pond with the TMDL implemented (2 ppb is 20% of the threshold goal for chlorophyll-a of 10 ppb). In the model runs, phosphorus levels measured in Berlin, NH in 2004 of 13 and 1 ppb for total-P, and ortho-P were assumed as inputs at the pond boundary. This is a low level of phosphorus that is close to natural conditions and free from significant non-point source impacts.

Implementation and Allocation of Phosphorus TMDL

The TMDL will be implemented by waste discharge licensing of point source discharges and the issuance of water quality certification for Gulf Island Dam. There are many possible ways in which loads can be allocated to point source discharges.   A single possible allocation method is illustrated. This method uses a combination of impact to the receiving water and average discharge levels of phosphorus measured for each point source in the summer of 2004.

The first step in determining the allocation, is to calculate the percentage of phosphorus assimilated in the river from the point of discharge to the entrance of Gulf Island Pond located at the Twin Bridges on Route 219 in Turner. This is done utilizing the Qual2EU model and individually including only one point source at a time and comparing the incremental phosphorus concentration differences at the outfall and Twin Bridges in a model run with all point sources removed. The phosphorus assimilation percentage can then be directly calculated. The following phosphorus assimilation percentages listed in Table 4 were obtained using this methodology.

Table 4 Phosphorus Assimilation of Androscoggin River

Point Source	% Phosphorus Remaining at Twin Bridges		% P- Assimilated from Outfall to Twin Bridges	
	Organic-P	Ortho-P	Organic-P	Ortho-P
Fraser	62.1%	1.7%	37.9%	98.3%
Berlin	60.7%	1.6%	39.3%	98.4%
Gorham	64.0%	3.9%	36.0%	96.1%
Bethel	65.5%	10.8%	34.5%	89.2%
Rumford-Mexico	82.8%	14.9%	17.2%	85.1%
Mead	79.6%	13.8%	20.4%	86.2%
IP	90.9%	97.6%	9.1%	2.4%
Livermore Falls	93.3%	98.4%	6.7%	1.6%

Different allocations can be easily considered by regulatory agencies in the licensing process by use of the trading ratios assuming that an individual point source allocation is lowered that could result in an additional amount of allocation to another point source. The trading ratios can also be used in an implementation strategy utilizing pollution trading by point source dischargers. The trading ratios are determined by the ratios of the phosphorus remaining for each point source at Twin Bridges. The trading ratios are summarized in Table 5.

Table 5 - Trading Ratios for Phosphorus

Trading Rules
U=Upstream Point Source
D= Downstream Point Source
T= Ratio stated in table for U vs D.
D gains 1 ppd for T ppd that U gives up.
U gains T ppd for 1 ppd that D gives up.

Ortho-P	Fraser	Mead	IP	Livermore Falls
Fraser		8.1	57.4	57.9
Mead	8.1		7.1	7.1
Int. Paper	57.4	7.1		1.0
Livermore Falls	57.9	7.1	1.0	

Organic-P	Fraser	Mead	IP	Livermore Falls
Fraser		1.3	1.5	1.5
Mead	1.3		1.1	1.2
IP	1.5	1.1		1.0
Livermore Falls	1.5	1.2	1.0	

Note: Trading ratios are derived from the ratios of % of phosphorus remaining at Twin Bridges.

Before presenting the default waste load allocations, the component analysis of phosphorus loads at the pond entrance for each contributor is presented using 2004 phosphorus discharge rates. The 2002 Modeling Report used loads at the point of discharge for the component analysis. The load at the pond entrance is actually what is relevant for contributing to algae blooms within the pond rather than loads at the outfall.

The component analysis of average phosphorus loads discharged in 2004 (Figure 10) indicates that paper mills are still the largest source of phosphorus and account for about 70% of the total-P and 80% of the ortho-P entering the pond. International Paper is the largest single source accounting for 45% of the total-P and 57% of the ortho-P entering the pond. MeadWestvaco is the second largest single source of phosphorus, accounting for about 14% of the total-P and 21% of the ortho-P entering the pond. All of the municipal discharges are an insignificant percentage of the total phosphorus entering the pond. However, Livermore Falls is nearly 13% of the ortho-P load entering the pond and can be considered to be a significant contributor of ortho-P. The Fraser Paper mill in Berlin, NH accounts for about 11% of the total-P entering the pond, but only 2% of the ortho-P entering the pond.

The allocation of each point source is initially set at the average phosphorus levels discharged in the summer of 2004. The reduction of allocation of phosphorus needed to meet the TMDL is made to the point source with the most contribution to algae blooms, International Paper. The total phosphorus allocation of all point sources is inflated by a clustering factor which accounts for the unlikelihood of all point sources discharging their maximum monthly loads simultaneously in any given summer. The clustering factors were derived by the phosphorus effluent monitoring of the paper mills in the summer of 2004. The cluster or load at Gulf Island Pond entrance is calculated for any given summer month by the summation of the product of the assimilation factors in Table 4 (% of phosphorus remaining at Twin Bridges) and the monthly average mill loads. The maximum cluster load for any given month in the summer is then compared as a ratio to the cluster load using the individual maximum monthly discharges from each mill for the summer of 2004 (this assumes the maximum loads from each mill are discharged simultaneously). The ratios derived from this process were 1.07 for ortho-P and 1.18 for organic-P. A 10% explicit margin of safety is then assigned to the total TMDL.

TMDL's must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between pollutant loads and water quality. EPA guidance explains that the MOS may be implicit, i.e. incorporated into the conservative assumptions used in the analysis, or explicit, i.e. expressed in loading set aside as a separate component of the TMDL. In this case an explicit margin of safety of 10% of the total TMDL was assigned to the total TMDL for all pollutants.

The 10% MOS resulted in the assignment of summer averaged phosphorus discharge rates from 2004 for most dischargers with the exception of International Paper whose ortho-P will be reduced from 37 to 22 ppd (Table 6). Since phosphorus limits are mass loads assigned as a monthly average license requirement, additional reductions for all of the mills from 2004 levels will be necessary.

The implementation being recommended for Berlin, Gorham, Bethel, and Rumford-Mexico is as follows. Collectively these discharges are 2.4% of the total-P load and 6.3% of the ortho-P load at the entrance to Gulf Island Pond. They have a *de-minimus* contribution to algae problems in the pond and for the initial stages of the TMDL should not have a phosphorus limit but should still be required to monitor phosphorus. The monitored phosphorus levels should be evaluated at the end of each summer to assure that the monitored phosphorus discharge rates do not exceed the assigned allocations.

The variability observed in the effluent monitoring of these four municipal discharges can be used to determine whether or not peak discharges of unregulated phosphorus from these sources is an issue in the next five years. First it should be mentioned that significant growth is not expected in these communities for the next five years, so phosphorus discharges should remain relatively stable during that time period. If the average phosphorus loads discharged from these facilities in the summer of 2004 as a cluster load entering Gulf Island Pond are compared to the monthly peaks experienced that summer, the peaks for total-P and ortho-P were 1.5 ppd and 0.4 ppd more, respectively or 20% and 12% higher, respectively. At 7Q10 flow, this results in concentration levels entering Gulf Island Pond that could potentially be 0.16 ppb and 0.04 ppb higher for total-P and ortho-P, respectively. This is within the measurement error of phosphorus and should not result in any noticeable increase in algae measured as chlorophyll-a.

The implementation being recommended for Livermore Falls is the assignment of an ortho-P limit. The ortho-P of Livermore Falls is nearly 13% of the load at the pond entrance and determined to be a significant contribution to algae blooms on the pond. In addition, this discharge is in a river segment of demonstrated low phosphorus assimilation so most of their ortho-P will reach the pond.

A footnote in Table 6 under implementation indicates that Fraser may be licensed with a total-P limit only with requirements to monitor ortho-P. A similar analysis to Fraser Paper's 2004 effluent monitoring data indicates that the variability of ortho-P that can be expected at the entrance to Gulf Island Pond due to Fraser's ortho-P load is 1.16 ppd which results in a potential increase of ortho-P of 0.13 ppb. When considered collectively with the municipal load variability (Berlin, Gorham, Bethel, Rumford-Mexico) the ortho-P concentration could potentially be 0.17 ppb higher than indicated by the TMDL. Once again, the potential impact to algae measured as chlorophyll-a should be neglible.

In this analysis the non-point source loads are those realized at the entrance to Gulf Island Pond after point source are removed from the model. The concentrations of phosphorus predicted by the model at the pond entrance under zero discharge is combined with the product of river flow and unit conversion factors to obtain non-point loads. As an important consideration, a monitoring end point should be recommended for the phased implementation of the TMDL. The implementation will involve stepped reductions of phosphorus for the paper mills and ongoing ambient monitoring in Gulf Island Pond. It is possible that phosphorus reductions less than suggested in the TMDL could result in the elimination of algae blooms. Conversely, implementation of the TMDL may not be enough to eliminate algae blooms. The following is recommended as an end point meaning that additional phosphorus reductions are no longer necessary.

<u>Monitoring End Point of Phased Implementation of TMDL</u> results when two summers of monitoring occurs without algae blooms when:

- Simultaneously both the river flow at Rumford < 2000 cfs and river temperature at Turner Bridge > 24^oC for a minimum of thirty consecutive days in each given summer. A flow of 2000 cfs is approximately 15% higher than 30Q10. The new TMDL is set 15% less than lowest phosphorus loading entering the pond during the two monitoring events or can be determined by modeling.

Or when one summer of monitoring occurs without algae blooms when

- Both the river flow at Rumford < 1740 cfs and river temperature at Turner Bridge > 24^oC for a minimum of thirty consecutive days for one given summer. A flow of 1740 cfs is the 30Q10 flow at Rumford. The new TMDL is set at actual phosphorus loading conditions entering the pond at the 30Q10 event or can be determined by modeling.

The ambient monitoring should be undertaken for a minimum of five years.

Carbonaceous Ultimate BOD TMDL
Oxygen Injection Requirements

The carbonaceous ultimate BOD (CBODu), and oxygen injection requirements are all dependent upon one another and discussed as a unit. The amount of oxygen injection is affected by the discharge amounts of paper mills, and to a lesser extent municipal discharges and non-point source pollution. Since paper mill inputs are the largest controllable source of BOD, the TMDL assigns loads accordingly here for implementation of the TMDL.

As outlined in 40 C.F.R. & 125.3(f), the use of non-treatment alternatives may be considered as a method of achieving water quality standards on a case-by-case basis when technology-based treatment requirements applicable to the discharge are not sufficient to achieve the standards. Such techniques must be the preferred environmental and economic method to achieve standards after the consideration of alternatives, such as advanced waste treatment and other available methods.

In the case of Gulf Island Pond, even if point sources are entirely removed, some degree of non-attainment of class C dissolved oxygen (DO) criteria is predicted to occur by the model (2002 Modeling Report). Hence attainment of water quality standards cannot be achieved solely through point source controls. Therefore this TMDL additionally requires the non-treatment alternative of oxygen injection to achieve water quality standards. The 125.3 demonstration will be submitted collectively by paper mills discharges prior to the licensing process. The wasteload allocations are predicated on the implementation of an oxygen injection strategy. It is permissible to assign less stringent WLA's to point sources in reliance on the non-treatment techniques where there is reasonable assurance that the non-treatment techniques will be implemented. In this case DEP intends to impose the requirements to implement oxygen injection in the permitting process for point sources.

The amount of dissolved oxygen non-attainment predicted by the model with point sources at zero discharge can be considered to be the impact related to the dam. While the dam itself does not create a pollutant load, it is a condition that contributes to the impairment for a number of reasons.

The dam slows down water movement resulting in a significant increase in the travel time of pollutants in the downstream direction. This creates conditions that are more favorable for algae blooms. Sediments accumulate on the bottom and are not easily flushed in an impoundment as large and deep as Gulf Island Pond resulting in a significant depletion of oxygen in deeper areas within the water column. BOD has more time to decay resulting in a larger deficit of dissolved oxygen than what would occur in a free-flowing river. Lastly the deepness of the impoundment promotes unfavorable mixing conditions vertically, which contributes to the low levels of oxygen in deep areas of the pond, and a greater probability of algae blooms in the top layers of Gulf Island Pond.

As stated earlier in the report there are limited opportunities for non-point source controls within this watershed that would be significant enough to make a difference in phosphorus loading during the summer season when non-attainment conditions occur in the pond. Hence control of non-point source pollution is not a feasible solution to address the non-attainment of DO criteria attributable to sediment oxygen demand. The dam owner should be responsible for this impact which is due only to the existence of the dam and impoundment. DEP intends to include a condition requiring oxygen injection in the water quality certification of the Gulf Island dam.

Since there are many different allocation possibilities, the DEP used a modeling run from April 15, 2003 are used as a starting point for establishing the TMDL. The modeling run was requested by paper mill personnel. They loads are as follows.

Table 7 - Loads from 4/15/03 Modeling Request

Paper Mill	BOD5		TSS
	Mo Ave	Week Ave	Mo Ave
Fraser	11000	15200	20000
Mead	9000	12500	15500
IP	8000	11100	25000

In Table 7, the weekly average BOD5 loads were not part of the request but were generated by dividing the monthly average BOD5 loads by 0.72. This value is the average ratio of the monthly average to weekly average BOD5 ratio as indicated by paper mill discharge monitoring reports. A weekly averaging period for river flow (7-day 10-year low flow) and temperature and point source inputs is used in the model assessment of minimum DO criteria. The modern 7Q10 that has been used historically by DEP for the Androscoggin River is 1550 cfs at Berlin NH based upon the minimum flow that is usually passed from the upper storage of the watershed. Based upon a drainage area adjustment factor of 0.086 cfs / square mile of drainage (see Flow Balance, Table 1, Androscoggin River Modeling Report, DEP, June 2002), this results in a flow of 1704 cfs through Gulf Island Pond. For the weekly average runs, a temperature of 24 ^{o}C was assigned in the river model and the temperature in the pond varied vertically from 26 ^{o}C on the surface to 24 ^{o}C near the bottom in most model reaches.

The temperatures assigned to the model at 7Q10 flow were derived from an analysis of the continuous monitoring data. The maximum weekly average temperatures that occurred each summer were computed for each monitoring year at the Turner Bridge, Deep Hole, and Gulf Island dam locations. The temperature assigned to the model is the average of the summer weekly maximums. The temperature assigned at locations not monitored directly was derived by a combination of interpolation and best professional judgment.

A 30-day averaging period is used in the assessment of 30-day average DO criteria. The modern 30Q10 is estimated by multiplying the 7Q10 by a factor of 1.05, as indicated by flow statistics at the Gorham NH USGS gage. This results in a 30Q10 flow of 1630 cfs at Berlin, NH and 1780 cfs through Gulf Island Pond.

The temperatures assigned to the model at 30Q10 flow followed a similar procedure to the weekly average temperatures at 7Q10 flow except that a 30-day averaging period was applied to the continuous monitoring data at Gulf Island Pond rather than a 7-day average. A temperature of 22 ^{o}C was used as the ceiling temperature over which significant growth for salmonid fish species is not expected to occur. The 30-day average DO criterion is needed to assure that adequate dissolved oxygen levels exist to support growth of salmonid species. The described analysis of the continuous monitoring data indicates that all of the areas in Gulf Island Pond can be expected to exceed 22 ^{o}C as a 30-day average in an average summer above the thermocline and hence this was the temperature assigned to the model in all reaches. A temperature of 22 ^{o}C was also assigned to the river reaches. Effluent loads are inputted as a monthly average.

In addition, a clustering factor was applied to the CBODu TMDL's similar to that of the phosphorus TMDL to account for the unlikelihood of all point source discharging their maximum loads simultaneously. The method for deriving the clustering factor is similar to that discussed in the phosphorus TMDL except the discharge monitoring data from the paper mills for the last four years is used to derive the cluster factors. This resulted in cluster factors of 1.09 for the 7-day CBODu TMDL and 1.06 for the 30-day CBODu TMDL. An explicit margin of safety of 10% is then applied to the total TMDL. The amount of oxygen injection needed in Gulf Island Pond must be obtained by a trial and error procedure in the model prediction run analysis.

In both the 7-day and 30-day CBODu TMDL's default and alternate allocations are presented. The default is based upon loads generated in the 4/15/03 modeling request and the alternate by each Maine mill having an equal amount of CBODu entering Gulf Island Pond. In the modeling discussed in the 2002 report, diurnal DO adjustments were not made to the Qual2EU water quality model of the river.[9] A diurnal DO adjustment is applied to the model runs presented here, based upon the data collected in the summer of 2004. When the diurnal DO range is not large, it is appropriate to use ½ of the range measured in the field data as a difference of the AM and PM data. As discussed in the November 2004 draft Data Report, diurnal DO fluctuations on the Androscoggin River are not large. The adjustment applied to the model ranged from a low of 0.2 ppm in the Livermore Falls and Virginia (Rumford Falls) impoundments to a high of 0.5 ppm in the shallow flowing section of river from Rumford to Dixfield.

When these loads are entered into to the Qual2EU model, non-attainment of minimum DO criteria (7 ppm) is predicted in the beginning of a class B segment from the Maine / New Hampshire border to the confluence of the Ellis River. Fraser Paper's weekly average BOD5 load must be reduced from 15200 to 11500 ppd. When these input loads are changed, attainment of minimum and daily average DO criteria are reached everywhere (Figure 11). Table 8 is a summary of the weekly average CBODu TMDL at the entrance to Gulf Island Pond along with a default allocation and alternate allocation of BOD5 to point sources. The TMDL is expressed as a weekly average load due to the averaging period used for flow and temperature (7 days). State law requires the use of 7Q10 flow for assessing the assimilation capacity of a river. Consistency with minimum DO criteria is evaluated by applying a diurnal adjustment factor to the model output to obtain the predicted daily minimum DO as explained in the previous paragraph.

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[9] The model prediction made at 7Q10 flow is an average DO over several days. Class C and B specifies minimum DO criteria, which must be maintained. An adjustment must be applied to the model output prediction to convert the average DO to a daily minimum DO. Bottom attached algae and phytoplankton are the major cause of diurnal fluctuations since algae produce oxygen during the daytime by photosynthesis and consumed oxygen at night time by respiration. Diurnal DO fluctuations would occur even without algae due to variability of the natural environment.

Table 8 Gulf Island Pond 7-Day Average TMDL CBODU PPD with Default and Alternate Allocations - Apply June to Sept

	Allocations at Outfall			Assimilation	Allocations Twin Bridges*	
Source	**Default** BOD5 4/15/03 Adjusted	**Alternate** BOD5 Allocate by = Impact	CBODu / BOD5	% BOD Remaining Twin Bridges*	**Default** Ultimate CBOD	**Alternate** Ultimate CBOD
NPS					9444	9444
Fraser	11500	11500	3.6	17.4%	7204	7204
Mead	12500	16940	3.6	31.9%	14355	19454
IP	11100	8795	3.5	63.2%	24553	19454
Berlin	991		Municipal Discharges are grouped in the TMDL due to their de-mimimus impact upon dissolved oxygen levels within Gulf Island Pond .			
Gorham	281					
Bethel	113					
Rum.-Mex	995					
Liv. Falls	750					
Munic Tot.	3130		3	39.1%	3671	3671
Total TMDL WLA (Point Sources) with clustering factor					**49783**	**49783**
WLA =Point Sources reduced by clustering factor					**45672**	**45672**
LA = Non-point Sources + Natural					**9444**	**9444**
Explicit Margin of Safety (10%)					**6124**	**6124**
TMDL Total					**61240**	**61240**

Oxygen Injection Load- Full attainment of DO criteria cannot occur without some amount of oxygen injection due to sediment oxygen demand.

*Twin Bridges or Rte 219 in Turner is the upstream boundary to Gulf Island Pond

Oxygen Load Requirements	Upper Narrows	Lower Narrows	Near Deep Hole	Efficiency
Default	30,000	150,000		0.333
Alternate #1	105,000	105,000		0.333
Alternate #2	50,000	65,000	42,000	0.333
Alternate #3	Other options are possible but must be approved by MDEP.			

Implementation of TMDL in Licensing

Point Source	Licensing Recommendation	Comment
Berlin Gorham Bethel Rumford-Mexico Livermore Falls	License as technology-based limits (BPT) year round.	Municipal discharges have a de-minimus impact to dissolved oxygen levels in Gulf Island Pond
Fraser Paper MeadWestvaco International Paper	Implement TMDL as limits that apply from June to Sept as a weekly average BOD5 load. Alternatively the mills could accept the TMDL implemented as a daily maximum BOD5 load with the following factors applied as a product to the weekly average TMDL; Fraser 1.4; MWV 1.5; IP 1.25 (ratios based upon DMR's). Require participation in oxygen injection system and ambient monitoring.	The paper mills have significant impact to dissolved oxygen levels in Gulf Island Pond.

Summary of Allocation Method.

1. Use paper mill loads based upon 4/15/03 paper mill modeling request or impact to Gulf Island Pond as initial basis. Weekly average loads derived from monthly load / 0.72. (The modeling request had no weekly average loads.)
2. Municipal allocations are technology based loads (design flow @ 45 ppm).
3. Fraser Paper load adjusted down to meet minimum class B DO criteria in the Androscoggin R from state line to Ellis R.
4. Point source allocations inflated by clustering factor of 1.09 which accounts for simultaneous loads to the pond. Clustering factor derived from DMR's.*
5. Explicit margin of safety of 10% applied to TMDL.
6. Instream Aeration needed as TMDL load due to the model prediction of non-attainment with all point sources removed.

* The clustering factor eliminates the assumption used in implicit margins of safety by MDEP, which assumes that all point sources discharge their maximum loads simultaneously.

In both allocation methods, the loads for all three mills are also water quality limited and could not be increased from the amounts in Table 8. As noted in Table 8, the weekly CBODu TMDL could also be implemented as a summer daily maximum permitted BOD5 load with the following factors applied as a product to the summer weekly average permitted BOD5 loads Fraser 1.4; MWV 1.5; and IP 1.25. These ratios were derived from four summers of discharge monitoring reports except for Fraser where two years were used due to the mill shutdown before that time period.

When the 30-day average dissolved oxygen criterion is tested, the model predicts that the 30-day average DO criterion of 6.5 ppm is met everywhere when point sources are at loads required in the TMDL (Figure 11). However since the criterion is just barely met at Livermore Falls, it can similarly be concluded that the monthly average loads required in the TMDL are water quality limited. The following table is a summary of the CBODu 30-day average TMDL at the entrance to Gulf Island Pond along with the same default and alternate allocations of BOD5 to point sources. The TMDL is expressed as a 30-day average to be consistent with the averaging period of 30 days for the load inputs, flow, temperature, and the DO criteria addressing growth of salmonid fish species.

Table 9 Gulf Island Pond 30-Day Average TMDL CBODU with Default and Alternate Allocations - Apply June to September

Source	Allocations at Outfall: Default BOD5 4/15/03 Adjusted	Allocations at Outfall: Alternate BOD5 Allocate by = Impact	CBODu / BOD5	Assimilation: % BOD Remaining Twin Bridges*	Allocations Twin Bridges*: Default Ultimate CBOD	Allocations Twin Bridges*: Alternate Ultimate CBOD
NPS					10440	10440
Fraser	10180	10180	3.6	24.7%	9052	9052
Mead	8330	9270	3.6	45.8%	13735	15285
IP	7400	6719	3.5	65.0%	16835	15285
Berlin	660		Municipal Discharges are grouped in the TMDL due to their de-mimimus impact upon dissolved oxygen levels within Gulf Island Pond .			
Gorham	188					
Bethel	75					
Rum.-Mex	663					
Liv. Falls	500					
Munic Tot.	2086		3	41.3%	2585	2585
Total TMDL WLA (Point Sources) with clustering factor					**42206**	**42206**
WLA =Point Sources reduced by clustering factor					**39817**	**39817**
LA = Non-point Sources + Natural					**10440**	**10440**
Explicit Margin of Safety (10%)					**5584**	**5584**
TMDL Total					**55841**	**55841**

Oxygen Injection Load- Full attainment of DO criteria cannot occur without some amount of oxygen injection due to sediment oxygen demand.

*Twin Bridges or Rte 219 in Turner is the upstream boundary to Gulf Island Pond

Oxygen Load Requirements	Upper Narrows	Lower Narrows	Near Deep Hole	Efficiency
Default	30,000	150,000		0.333
Alternate #1	105,000	105,000		0.333
Alternate #2	50,000	65,000	42,000	0.333
Alternate #3	Other options are possible but must be approved by MDEP.			

Implementation of TMDL in Licensing

Point Source	Licensing Recommendation	Comment
Berlin Gorham Bethel Rumford-Mexico Livermore Falls	License as technology-based limits (BPT) year round.	Municipal discharges have a de-minimus impact to dissolved oxygen levels in Gulf Island Pond
Fraser Paper MeadWestvaco International Paper	Implement TMDL as limits that apply from June to Sept as a monthly average BOD5 load. . Require participation in oxygen injection system and ambient monitoring.	The paper mills have significant impact to dissolved oxygen levels in Gulf Island Pond.

Summary of Allocation Method.

1. Use paper mill loads based upon 4/15/03 paper mill modeling request or impact to Gulf Island Pond as initial basis.
2. Municipal allocations are technology based loads (design flow @ 30 ppm).
3. Fraser Paper load limited by meeting weekly average CBODu TMDL sample allocation = 11500 ppd.
4. Point source allocations inflated by clustering factor of 1.06 which accounts for simultaneous loads to the pond. Clustering factor derived from DMR's.*
5. Explicit margin of safety of 10% applied to TMDL.
6. Instream Aeration needed as TMDL load due to the model prediction of non-attainment with all point sources removed.

* The clustering factor eliminates the assumption used in implicit margins of safety by MDEP, which assumes that all point sources discharge their maximum loads simultaneously.

The model runs made by Qual2EU simulate water quality conditions in the river from Berlin to Turner. The terminal conditions at the end of the last modeled reach (Twin Bridges sampling location) become the boundary conditions for the WASP model, which simulates water quality of Gulf Island Pond. Each prediction run is a two step process involving both models.

In Gulf Island Pond, the river is classified as C requiring the daily minimum dissolved oxygen not be less than 5 ppm and 60% of saturation. New legislation states that dissolved oxygen readings below a point 0.5 meters from the bottom of the pond and below the point of thermal stratification[10] (bold face line in Figures 12 - 21) should not be considered in a compliance evaluation for dissolved oxygen. The DEP is applying the 30-day average dissolved oxygen of 6.5 ppm only at temperatures less than or equal to 24 ^{o}C on the Androscoggin River in order to meet the present narrative standards in class C water quality criteria listed at 38 MRSA &465 4 (b).

Model prediction runs in Gulf Island Pond were made for five different cases. The model prediction run results are presented in schematics of the pond similar to the format followed in the 2002 modeling report (Figures 12-21). The following is a summary of model prediction run results.

1. Current licensed loading of point sources and current oxygen injection requirements at one injection location at Upper Narrows.
    - Non-attainment of DO criteria occurs from a depth of 10 to 60 feet for periods of time during the summer at some locations (Figures 12 and 13).

2. TMDL loads implemented, but with only current oxygen injection requirements at one injection location at Upper Narrows.
    - Non-attainment of DO criteria occurs from a depth of 20 to 60 feet for periods of time during the summer at some locations (Figures 14 and 15).

3. TMDL loads implemented with additional oxygen injection involving two injection points; one at Upper Narrows and the other at Lower Narrows.
    - DO criteria can be met everywhere above the thermocline with oxygen injection rates of 30,000 ppd at Upper Narrows and 150,000 ppd at Lower Narrows assuming an oxygen transfer efficiency of 1/3 (Figures 16 and 18). This is the default oxygen injection strategy.
    - DO criteria can also be met everywhere above the thermocline with oxygen injection rates of 105,000 ppd at Upper Narrows and 105,000 ppd at Lower Narrows assuming an oxygen transfer efficiency of 1/3 (Figures 17 and 19). This is an alternate oxygen injection strategy.

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[10] The point of thermal stratification (thermocline) is defined as the depth where a change in water temperature of greater than 1^{o}C per meter of depth occurs.

4. TMDL loads implemented with additional oxygen injection involving three injection points - Upper Narrow, Lower Narrows, and just above the Deep Hole.
    - DO criteria can be met everywhere above the thermocline with oxygen injection rates of 50,000 ppd at Upper Narrows, 65,000 ppd at Lower Narrows and 42,000 ppd above the Deep Hole assuming an oxygen transfer efficiency of 1/3 (Figures 20 and 21). This is an alternate oxygen injection strategy.

5. Point Sources at Zero-Discharge with and without oxygen injection
    - With no oxygen injection, DO criteria can only be maintained to a depth of 30 feet for periods of time during the summer at some locations (Figures 22, 23).
    - DO criteria can be met everywhere above the thermocline if oxygen is injected at 65,000 ppd at Lower Narrows assuming an oxygen transfer efficiency. of 1/3 (Figures 24, 25).
    - DO criteria can also be met everywhere above the thermocline if oxygen is injected at 105,000 ppd at Upper Narrows assuming an oxygen transfer efficiency. of 1/3 (Figures 26, 27).

In the 7-day and 30-day model simulations, one default and two alternate aeration strategies needed to meet the TMDL are presented. Many other designs are also possible. The strategies presented assume an oxygen transfer efficiency of 1/3 to the water column which is the estimated efficiency of the current oxygen injection system. The efficiency of the current system could be greatly improved so that lesser amounts of oxygen injection are possible. A third alternate aeration strategy is included indicating that many other systems are possible, but must have DEP approval to assure that dissolved oxygen criteria within Gulf Island Pond will still be maintained and no localized problems within the river will occur. DEP plans to include language in the licensing of waste discharges that allows flexibility provided that other designs are DEP approved.

In any of the prediction runs, the model predicts some non-attainment of DO criteria in the deeper segments directly above the oxygen diffuser located at Upper Narrows as indicated in an excerpt of the pond schematic shown below.

Model Schematic of Segments 8 - 16

Segments with predicted DO non-attainment

Turner Bridge		Upper Narrows
8	11	14
9	12	15
10	13	16

The non-attainment predicted in these two segments is believed to be not representative of actual conditions. The model calibration points were at Turner Bridge (model segments 8, 9, 10) and Upper Narrows (model segments 14, 15, 16). The DO non-attainment is predicted in segments in-between these two points (model segments 12, 13). The predictions for low DO on many other deep locations closer to the dam has been verified by actual data. The sampling location in 2004 was set up above the oxygen diffuser or an area represented in the model by segments 11, 12, and 13. DO readings here attained class C minimum and 30-day average DO criteria all summer. It is recommended that monitoring continue here in the future to confirm that this would also be the case during a summer low-flow and high temperature conditions.

TSS TMDL

Total suspended solids (TSS) are relevant to the TMDL to Gulf Island Pond due to its contribution to the sediment oxygen demand of Gulf Island Pond. TSS is also the pollutant of concern to water quality in the Livermore Falls impoundment where it contributes to aquatic life non-attainment. Two separate TMDL's will be set for TSS based upon both of these factors.

The TSS TMDL for Gulf Island Pond is needed to assure sediment oxygen demand will not significantly increase. The phosphorus TMDL is also important for controlling sediment oxygen demand. A calculation process for determining the various components of sediment oxygen demand in Gulf Island Pond is explained in detail in the Androscoggin River Modeling Report (June 2002). The TSS loads that originate from the April 15, 2003 modeling are used as a basis for determining the TMDL. The mill loads are then proportionally reduced to allow for a 10% explicit margin of safety. The oxygen injection requirements outlined in the proceeding section are a necessary component of the TMDL for both TSS and CBODu. A summary of the TSS TMDL and a sample allocation method is outlined below (Table 10). This TMDL addresses the accumulation of solids over a long time period and their contribution to sediment oxygen demand. Such analyses are typically undertaken over an annual time scale and hence the TMDL is expressed as an annual average.

Table 10 Gulf Island Pond TSS TMDL as Annual Average ppd with Default and Alternate Allocations							
Source	Allocations at Outfall			Assimilation	Allocations at Twin Bridges		
	Default = Impact	**Alternate #1** 4/15/2003	**Alternate #2** = ppd	% Remaining Twin Bridges	**Default** = Impact	**Alternate #1** 4/15/2003	**Alternate #2** = ppd
NPS					47907	47907	47907
Fraser	18959	16170	16283	71.0%	13461	11481	11561
Mead	15836	12170	16283	85.0%	13461	10345	13841
IP	14630	20170	16283	92.0%	13460	18556	14980
Berlin	660			Municipal Discharges are grouped in the TMDL due to their de-mimimus impact upon dissolved oxygen levels within Gulf Island Pond .			
Gorham	188						
Bethel	75						
Rumford-Mexico	663						
Livermore Falls	500						
Total Municipal	2086			82.0%	1711	1711	1711
WLA = Point Sources				**42093**	**42093**	**42093**	**42093**
LA = Non-point Sources				**47907**	**47907**	**47907**	**47907**
Explicit Margin of Safety 10%				**10000**	**10000**	**10000**	**10000**
TMDL Total				**100000**	**100000**	**100000**	**100000**

Implementation of TMDL in Licensing

Point Source	Licensing Recommendation	Comment
Berlin Gorham Bethel Rumford-Mexico Livermore Falls	License as technology-based limits (BPT) year round.	Municipal discharges have a de-minimus impact to sediment oxygen demand and dissolved oxygen levels in Gulf Island Pond
Fraser Paper MeadWestvaco International Paper	Implement TMDL as an annual average TSS limit. This will limit mill discharges to current levels to assure that sediment oxygen demand within Gulf Island Pond does not increase.	The paper mills have significant impact to sediment oxygen demand and dissolved oxygen levels in Gulf Island Pond.

Summary of Allocation Method.

1. The annual TSS TMDL is needed to assure that sediment oxygen demand levels in Gulf Island Pond do not increase.
2. Use paper mill loads based upon 4/15/03 paper mill modeling request or impact to Gulf Island Pond as initial basis.
3. Municipal allocations are technology based loads (design flow @ 30 ppm).
4. Paper Mill loads are reduced from 4/15/03 basis to preserve explicit MOS.

The TMDL for TSS in the Livermore Falls impoundment uses macro-invertebrate sampling and a linear discriminate model to determine attainment / non-attainment status. The TSS loads discharged to the Androscoggin River during the time that rock basket samplers for macro-invertebrates were placed in the river are compared to attainment / non-attainment status of aquatic life criteria. Model runs were made by Qual2EU to determine actual TSS loads to the Livermore Falls impoundment. The Qual2EU model accounts for TSS lost in the river through settling from the point of discharge to the Livermore Falls impoundment. A TSS settling rate of 0.10 per day was used in the model runs. This rate was calibrated with actual data (see Androscoggin River Modeling Report, June 2002). A summary of conditions and results during aquatic life sampling are as follows:

Table 11 - Conditions During Aquatic Life Sampling							Aquatic Life Criteria Status Class			
	Flow Rumford cfs	Temp Jay °C	Intermittant Drainage CFSM*	Int Paper TSS PPD	Mead WV TSS PPD	Fraser TSS PPD	Liv Falls Imp	Lower Otis Imp	Upper Otis Imp.	Upper Middle Jay Imp.
June- Aug 95	1920	23.5	0.48	19804	10607	8133	N/A	N/A	N/A	B
Aug Sept 96	2715	20.6	0.62	5750	6398	10100		C	B	B
June-Aug 00	2432	20.7	0.97	9300	4920	10012	C	C	B	B
July Aug 02	2040	24.0	0.58	9100	4000	2062	N/A	C	C	B
June Aug 03	2370	22.4	0.90	10700	5120	7304	C	C	B	B
July-Aug 04	2440	23.1	0.88	7650	3800	10227	B			

*CFSM = Cubic feet per second per square mile of drainage. N/A = Non-attainment of Class C

It can be observed that class C aquatic life criteria were not met in the summers of 1995 and 2002, the two years of lowest mean flow during the sample period. A summary of actual loads to the Livermore Falls impoundment during each of these years is as follows:

Table 12 - TSS Loads in ppd to Livermore Falls Impoundment - Class C						
	Fraser	Mead WV	Int. Paper	Non-Point	Total	Aquatic Life Status
June- Aug 95	4659	8295	19804	7200	40258	Non-attainment
June-Aug 00	5735	3773	9300	11400	30508	C
July Aug 02	965	3014	9100	7900	21279	Non-attainment
June Aug 03	4118	3976	10700	10200	29294	C
July-Aug 04	6305	2852	7650	7700	24807	B

In the total loads estimated to the Livermore Falls impoundment, the municipal contribution is assumed to be about 300 ppd. Data collected in 1999 are used to assign the boundary TSS concentration in Berlin of 1 ppm. Non-point TSS concentrations are assumed to be consistent in any given summer that was analyzed. The differences in non-point source TSS loads from year to year are due to differences in river flow. When river and tributary flows are higher, non-point TSS loads are higher.

When total TSS loads are compared to the evaluations of aquatic life criteria, the 2002 assessment appears inconsistent with assessments in 2000, 2003, and 2004. The lowest TSS load to the Livermore Falls impoundment occurred in 2002, yet non-attainment of class C aquatic life criteria occurred in that summer. The TSS loads that occurred in 2000 and 2003 are about 40% higher but class C aquatic life criteria were met in those years. In the summer of 2004, the TSS load to the Livermore Falls impoundment was 16% higher than 2002, but class B aquatic life criteria was met in 2004. River flow was about 16% to 19% lower in 2002 compared to the other three years, but this difference is probably not large enough to explain the apparent inconsistency in the 2002 results of macro-invertebrate sampling. Another factor DEP has considered to explain the aquatic life non-attainment in 2002 is the lack of a large runoff event that could help to flush the river bottom of solids that have settled onto benthic organisms (Figure 28). The summers of 2003 and 2004 contained a number of runoff events that could have potentially flushed the river and cleansed the bottom of settled solids. The rock baskets used for macro-invertebrate sampling were typically placed in the Androscoggin River in the months of July and August. It is possible that very large flushing events that occurred in June prior to the placement of samplers could also have flushed the river bottom.

The summer of 2000 contained only one large runoff event in July to August. It is unlikely that the moderately elevated flow from this one event would be enough to flush the river bottom. The summer of 2002 started with very high flows in June up to mid-July and an extended period of virtually no run-off from mid July to the end of August. A similar summer lacking runoff occurred in 2001, although no macro-invertebrate sampling occurred that year. Without additional macroinvertebrate data collected under low flow and low runoff, it is difficult to explain the apparent contradiction of the 2000 and 2002 aquatic life evaluations, and the relationship of TSS and flow to aquatic life attainment.

For this TMDL calculation, a phased implementation will be used in which the 2002 data will not be used to set an initial TMDL until more data can be collected at summer low flow conditions to confirm whether or not the lack of flushing also contributes to aquatic life non-attainment. After the collection of an additional aquatic life data set and evaluation of attainment status at extended low flow conditions, the TMDL should be re-evaluated. It is suggested that if extended low flow conditions look likely in any given summer, that hydrologic flushing of the impoundment also be investigated as a possible implementation strategy.

Another possible explanation for the apparent inconsistency in the data is that shorter term peaks of TSS from the mills results in non-attainment of aquatic life criteria through an acute event rather than a chronic event such as sixty days that is being used as the averaging time period of the TMDL. It is suggested that this possibility be further explored in the phased implementation of the TMDL when causes to aquatic life non-attainment status are being investigated in the future.

The TMDL uses a clustering factor of 1.06 to account for the unlikelihood of all point sources discharging their maximum 60-day average TSS simultaneously in any given summer. This clustering concept is similarly used in the phosphorus and CBODu TMDL's and the reader should refer to these sections for a more detailed explanation. An explicit margin of safety of 10% is applied to the total TMDL. The following TMDL for TSS in the summer (June to September) results using the other four years. One default allocation based upon impact to the Livermore Falls impoundment and two possible alternate allocation methods are presented. A 60-day averaging period is used due to the time period required for the samplers used to evaluate aquatic life attainment status.

Table 13 Livermore Falls Impoundment TSS TMDL as a 60-Day Average ppd (June-Sept) with Default and Alternate Allocations							
	TSS Allocations at Outfall in ppd			Assimilation	TSS Allocations at Livermore Falls ppd		
Source	**Default** = Impact	**Alternate #1**	**Alternate #2** = PPD	% Remaining Twin Bridges	**Default** = Impact	**Alternate #1**	**Alternate #2** = PPD
NPS					7800	7800	7800
Fraser	16600	14800	11060	50.0%	8628	8385	5530
Mead	11000	10000	11060	75.0%	8628	7500	8295
IP	8300	10000	11060	100.0%	8628	10000	11060
Berlin	660			Municipal Discharges are grouped in the TMDL due to their de-mimimus impact upon dissolved oxygen levels within Gulf Island Pond .			
Gorham	188						
Bethel	75						
Rumford-Mexico	663						
Municipal*	1587	1587	1587				
Total TMDL WLA (Point Sources) with clustering factor					25885	25885	25885
WLA =Point Sources reduced by clustering factor					**24420**	**24420**	**24420**
LA = Non-point Sources + Natural					**7800**	**7800**	**7800**
Explicit Margin of Safety (10%)					**3580**	**3580**	**3580**
TMDL Total					**35800**	**35800**	**35800**

Implementation of TMDL in Licensing

Point Source	Licensing Recommendation	Comment
Berlin Gorham Bethel Rumford-Mexico Livermore Falls	License as technology-based limits (BPT) year round.	Municipal discharges have a de-minimus impact to aquatic life in the Livermore Falls impoundment.
Fraser Paper MeadWestvaco International Paper	Implement TMDL as 60-day average TSS limit from June - Sept. Require ambient monitoring of aquatic life. Require the investigation of hydrologic flushing in the Livermore Falls impoundment.	The paper mills affect aquatic life criteria attainment in the Livermore Falls impoundment.

Summary of Allocation Method.

1. The 60-day average TSS TMDL is needed to meet aquatic life criteria in the Livermore Falls impoundment.
2. Paper mill loads discharged during aquatic life sampling used as basis to set paper mill limits.
3. Municipal allocations are technology based loads (design flow @ 30 ppm).

4. A clustering factor of 1.06 is applied to the TMDL to account for the unlikelihood of all point sources discharging their summer 60-day average maximums simultaneously. Clustering factor is derived from the mill discharge monitoring reports.
5. An explicit margin of safety of 10% is applied to the total TMDL.

The TMDL splits the difference of TSS loads known to cause aquatic life non-attainment (40258 ppd) and loads that did not cause non-attainment (30508 ppd). Summer macroinvertebrate sampling will be a yearly requirement until more data can be collected during extended low flow conditions.

Table 13 provides a default TSS allocation for the three paper mills based upon equal impact to the Livermore Falls impoundment and two other alternate allocation methods. Other allocation methods are also possible. Pollution trading between the paper mills or municipal point sources is also a possibility. The trading ratio for International Paper, MeadWestvaco, and Fraser Paper are presented in Table 14. Note that regulatory agencies can also use the trading ratios to consider different allocations in the licensing process that would still provide an equal amount of protection in the licensing process.

Table 14 - Trading Ratios for TSS as a 60-Day Average

Trading Rules
U=Upstream Point Source
D= Downstream Point Source
T= Ratio stated in table for U vs D.
D gains 1 ppd for T ppd that U gives up.
U gains T ppd for 1 ppd that D gives up.

TSS	Fraser	Mead	IP
Fraser		1.5	2
Mead	1.5		1.33
International Paper	2.0	1.3	

Note:Trading ratios are derived from the ratios of % TSS remaining at Liv. Falls.

Water Quality Model Sensitivity Analysis

In a model sensitivity analysis, parameter rates, or inputs are varied and the model output prediction for variables of interest such as dissolved oxygen or chlorophyll-a are observed and compared with one another. It can then be determined which parameters or inputs are most important for influencing the model's prediction.

The 2002 Modeling Report investigated the importance of sediment oxygen demand, oxygen injection, and paper mill BOD input levels upon the model prediction of dissolved oxygen. Sediment oxygen demand (SOD) was found to be the most important since the model prediction of DO changed the most within given percentages of change for SOD. Varying oxygen injection rates resulted in the second largest response to model prediction of DO and the amounts input for the paper mill BOD inputs resulted in the lowest response of the model DO. This is a useful exercise in showing that reducing pollutants that contribute to SOD (algae, TSS) and oxygen injection are more efficient cleanup actions than reducing paper mill BOD.

The sensitivity analysis undertaken for this report will investigate model responses for predicted chlorophyll-a by varying the following; the OP mineralization rate, light saturated intensity, fraction of dead algae recycled to organic-P, and the boundary ortho-P concentration. The model was run with the OP mineralization rate at 0.02, 0.03, 0.04, and 0.05 per day; the saturated light intensity at 175, 200, 250, and 300 langleys ; the fraction for recycling to organic-P at 0.5, 0.6, 0.7; and boundary ortho-p at 5.5, 6, 7, and 8 ppb. The results show that the model is equally sensitive to changes in the OP mineralization rate and the fraction of dead algae recycled to OP rate, but insensitive to changes in the saturated light intensity (Figures 23 and 24). Within the ranges investigated, the model showed moderate sensitivity to changes in the boundary ortho-P.

Discussion of the Dead River

The Dead River was sampled weekly during the summer of 2004 at two locations, usually on the day after the sampling of the Androscoggin River and Gulf Island Pond. Class B DO criteria were met in the Route 106 sampling location all summer. Non-attainment of class B dissolved oxygen criteria occurred on at least three occasions at the lower sampling station below the dam in Leeds. Algae blooms has also been a water quality issue on the Dead River. During the aerial monitoring of algae blooms by DEP in the summer of 2004, mild algae blooms were observed on the Dead River from the plane on two occasions. In addition algae blooms have been reported on the Dead River in summers subsequent to 2004 by local residents. As will be explained below, the Dead River is a very complex and unique system and much more data collection is needed to fully determine how the system functions.

The temperature data taken at one-meter depth increments in 2004 at both Dead River locations indicates that a high amount of thermal stratification occurs. The thermal stratification appears to be much stronger at the sampling location below the dam. The temperature gradient here from the water surface to the bottom depth of three meters of $5^{o}C$ or more occurred from late July to the end of August. The lack of water movement of the Dead River flow below the dam to the confluence of the Androscoggin River (about one mile in length) is the reason for the strong thermal stratification.

The Dead River is unique from many tributaries in that flow reverses direction during higher flow events.[11] The flow is actually the Androscoggin River backing up the Dead River up to the dam. With the information collected to date, it is still unclear if the Androscoggin River backs up to the Dead River dam at low flow events approaching 7Q10. The dam also impedes flow movement up the Dead River. In this situation, flow released from the Dead River dam is trapped and becomes stagnant. The lack of water movement and stagnation that results is a large contributing factor to the non-attainment of class B minimum DO criteria.

At Androscoggin River flow events exceeding 16,000 cfs, back flow overtops the dam and pollutants from the Androscoggin River may reach Androscoggin Lake. The dam and its three-foot flashboards are part of a DEP and stakeholder management strategy to minimize pollutant loads from the Androscoggin River to Androscoggin Lake. An important part of this strategy is the maintenance of the flashboards to assure that failure of the three foot boards does not occur during a high flow event.

[11] A similar back flow situation occurs in the Little Androscoggin River drainage for Hogan and Whitney Ponds.

The Androscoggin River water temperature is usually warmer than the Dead River water temperature in the latter part of the summer when thermal stratification occurs. When the Androscoggin River is backing up the Dead River during this time, it flows over the surface of the Dead River water released from the dam. The Dead River water is trapped below the Androscoggin River back flow.

Some stakeholders have suggested that point source discharges on the Androscoggin River may be contributing to the dissolved oxygen non-attainment measured below the Dead River Dam. Since larger rivers do not ordinarily influence water quality of their tributaries, with the data collected to date on the Dead River, DEP does not yet support this conclusion. The relationship between the Androscoggin River stage as related to the Dead River stage at low flow conditions is not fully understood. It is critical to obtain the information before any conclusions can be made about the pollutant sources that are likely responsible for the dissolved oxygen depletion on the Dead River.

Point source phosphorus contributions to Androscoggin Lake during backflow events that overtop the dam have been calculated by the DEP lakes assessment section[12] to be only 0.4% of the annual phosphorus load to the lake. Hence regulation of point source phosphorus discharges to improve Androscoggin Lake water quality would not prove to be very effective, since point sources are such a small proportion of the phosphorus load to the lake. In this assessment, the phosphorus loads within the Androscoggin Lake watershed were calculated to be the major source of phosphorus accounting for about 78% of the annual phosphorus load to Androscoggin Lake. Non-point sources originating from the Androscoggin River watershed were calculated to be slightly fewer than 8% of the annual phosphorus load to Androscoggin Lake. Internal loading within the lake is estimated to be about 14% of the annual phosphorus load.

Additional data collection on the Dead River in the future could include the following:

- Stage readings at the Dead River and Androscoggin River confluence and below the Dead River dam to better establish if back flow events occur at low flow conditions.
- DO and temperature profiles, chlorophyll-a, secchi depth, total-P, and ortho-P at additional locations in the Dead River above and below the dam.
- Conductivity profile readings in the Dead River at locations directly above dam and below dam at many locations. Also in Androscoggin River above the Dead River confluence. Conductivity of the Dead River and the Androscoggin River water should be much different and this could help establish what is occurring hydraulically.
- Ultimate BOD on the Androscoggin River above the Dead River confluence and in some locations on the Dead River below the dam.

[12] Androscoggin Lake – Dead River Phosphorus and Hydrologic Loading Analysis, MDEP, August 2003. Estimated provided as percentages of annual phosphorus loads are for the current dam in place with three foot flashboards with the assumption that the flashboards will be maintained to prevent failure.